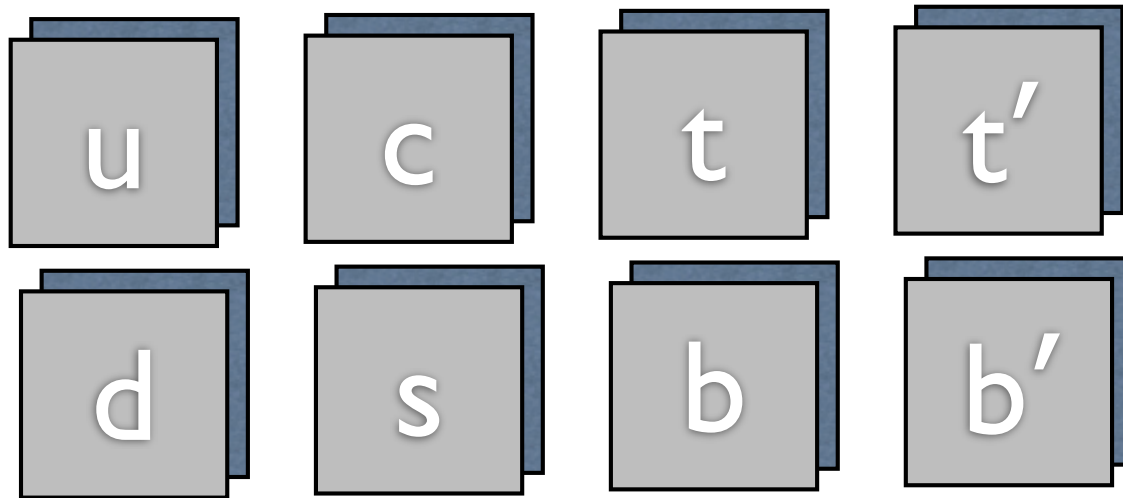# Search for Fourth Generation Quarks in CDF

John Conway
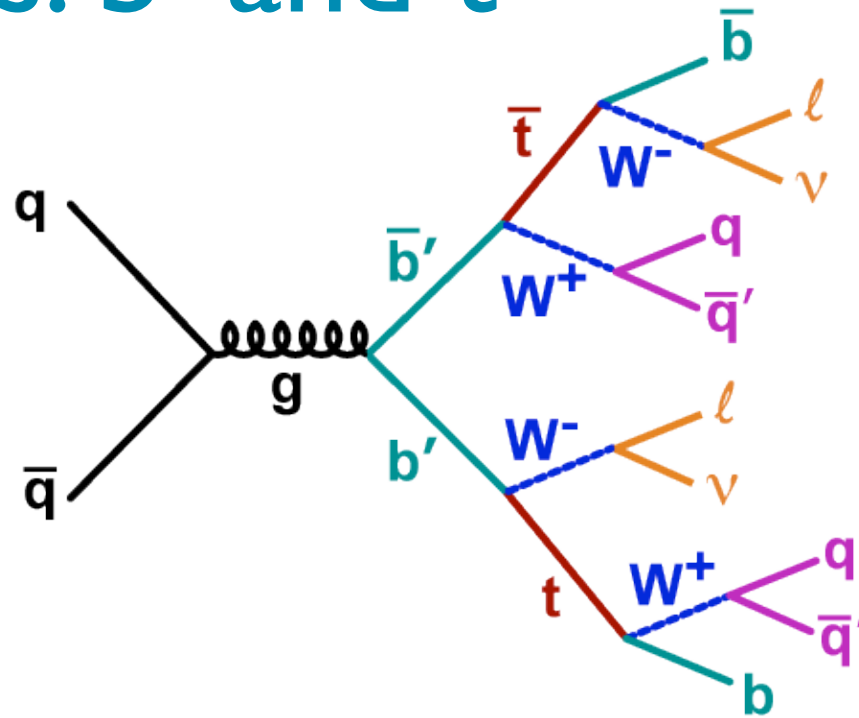## Univ. of California, Davis

Brookhaven Forum, May 2010

Another quark generation?

- not forbidden (therefore compulsory?)

- would have big effect on Higgs sector

- leptons too? if so, $m(\nu_4) > 50$ GeV
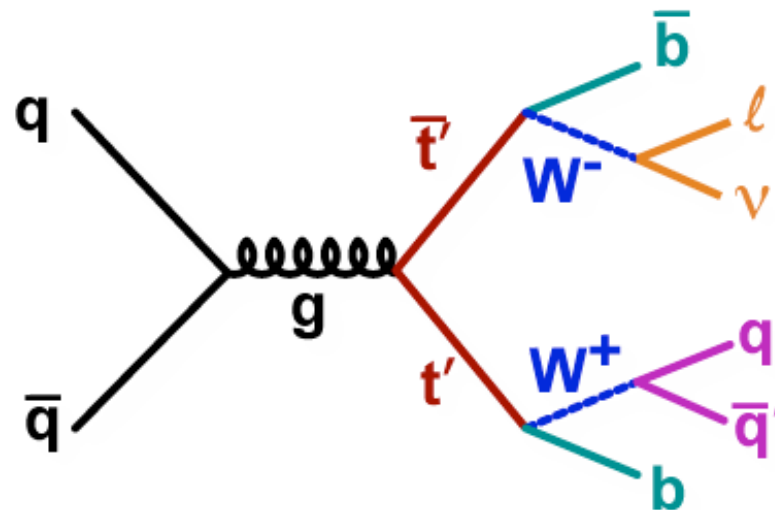
- may not be simple sequential generation...

CDF analyses: b′ and t′

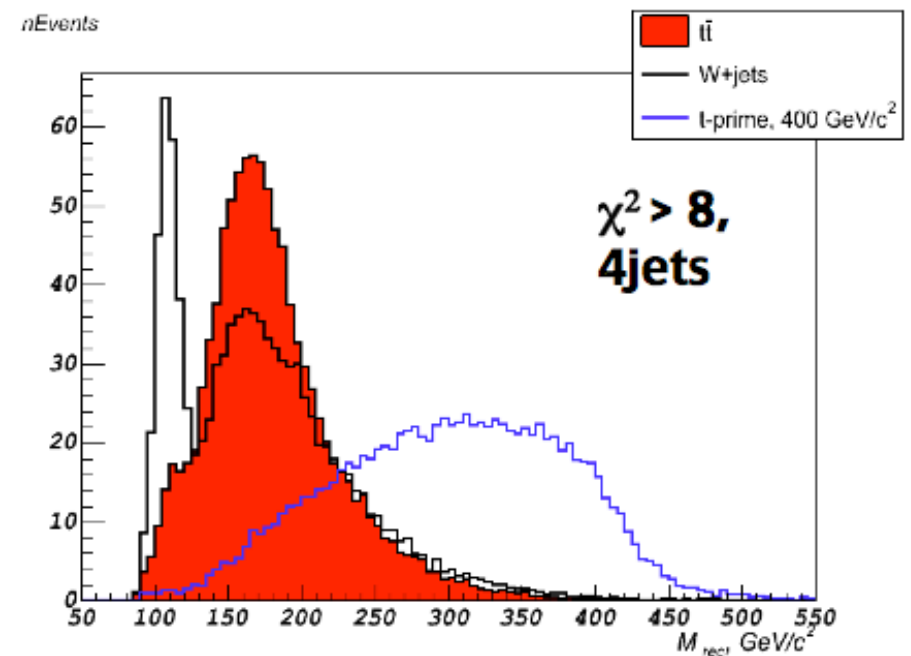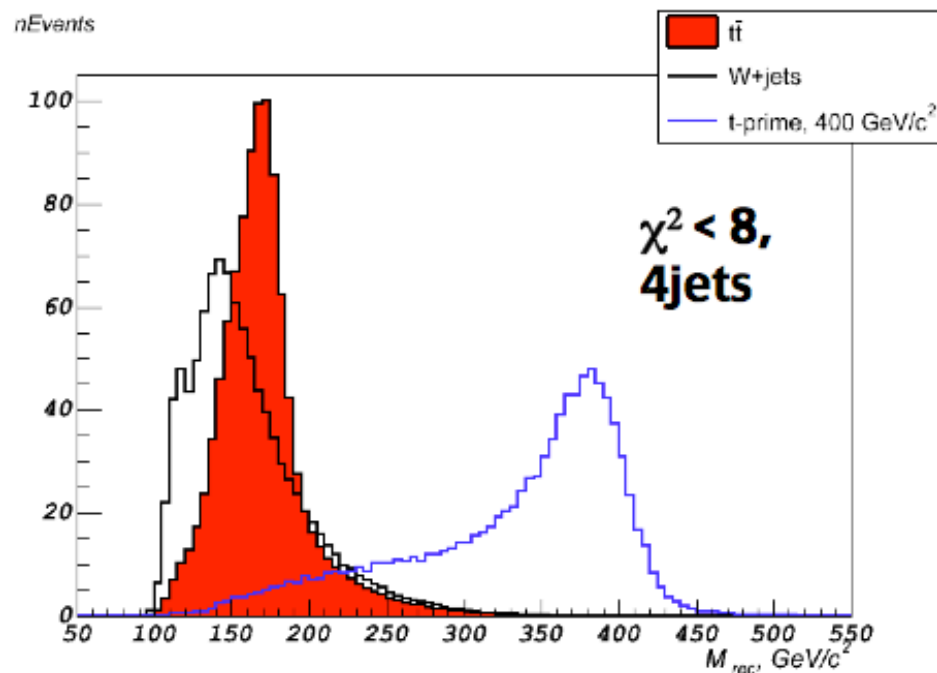- b′: look for LS dilepton+jets +MET events

2.7 fb⁻¹
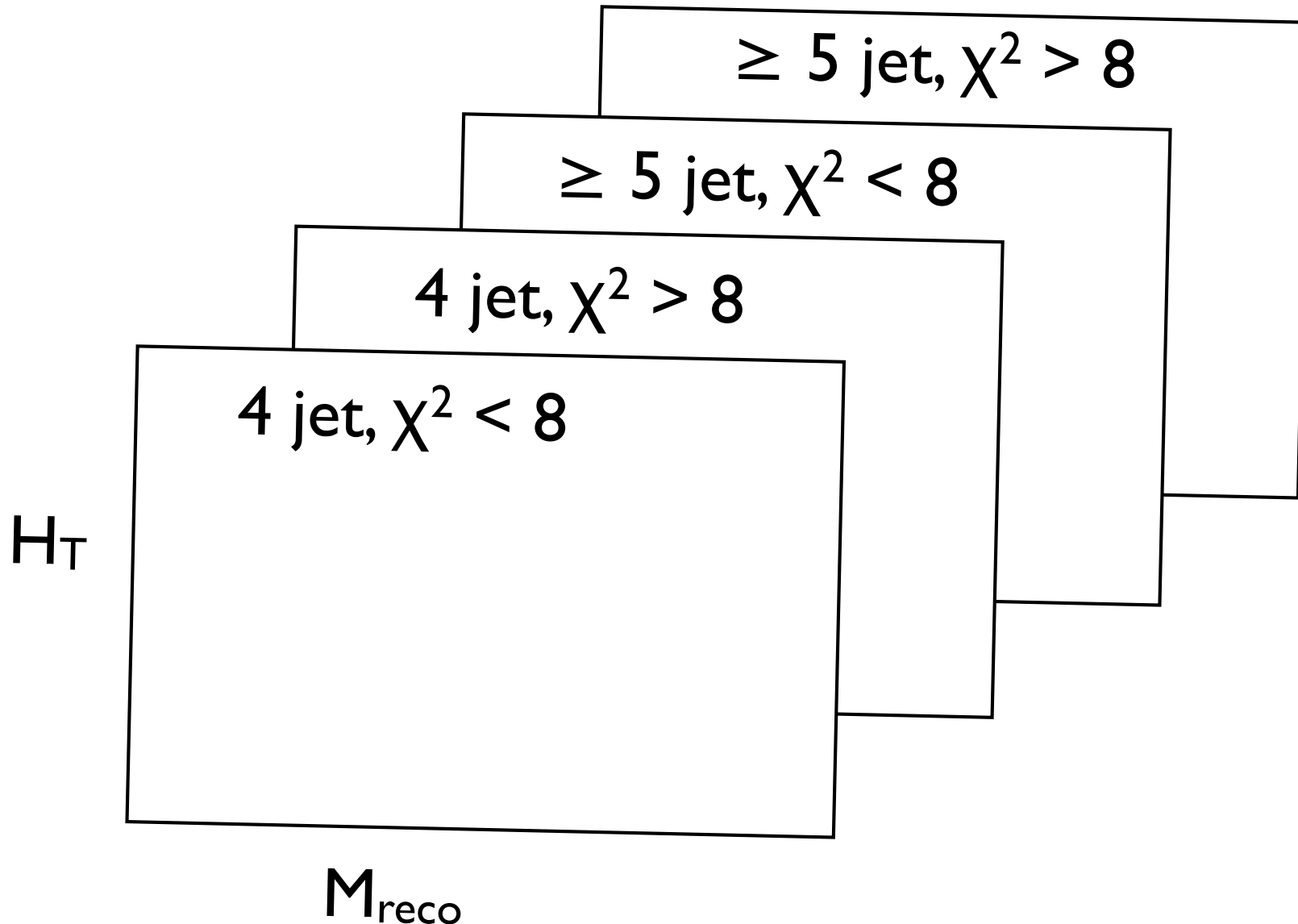
- t′: look for lepton+jets +MET events

4.6 fb⁻¹

Search strategy for t'

- select lepton plus jets events

- reconstruct t' mass using mass fitter

- fit in multidimensional space: H_T, M_{reco}, N_{jet}/χ^2

"3D" fit for t'

- H_T vs M_{reco}, vs jet category:

≥ 5 jet, $\chi^2 > 8$

≥ 5 jet, $\chi^2 < 8$

4 jet, $\chi^2 > 8$

4 jet, $\chi^2 < 8$

H_T

M_{reco}

Likelihood approach

- use binned poisson likelihood in all three dimensions

- represent all systematic errors as nuisance parameters in likelihood; remove by profiling

- obtain posterior in signal cross section using Bayes theorem

- integrate to find 95% CL upper limit on signal assuming uniform prior (up to cutoff)

Systematics in t' analysis

Three kinds; all gaussian-constrained:

1. normalization uncertainties
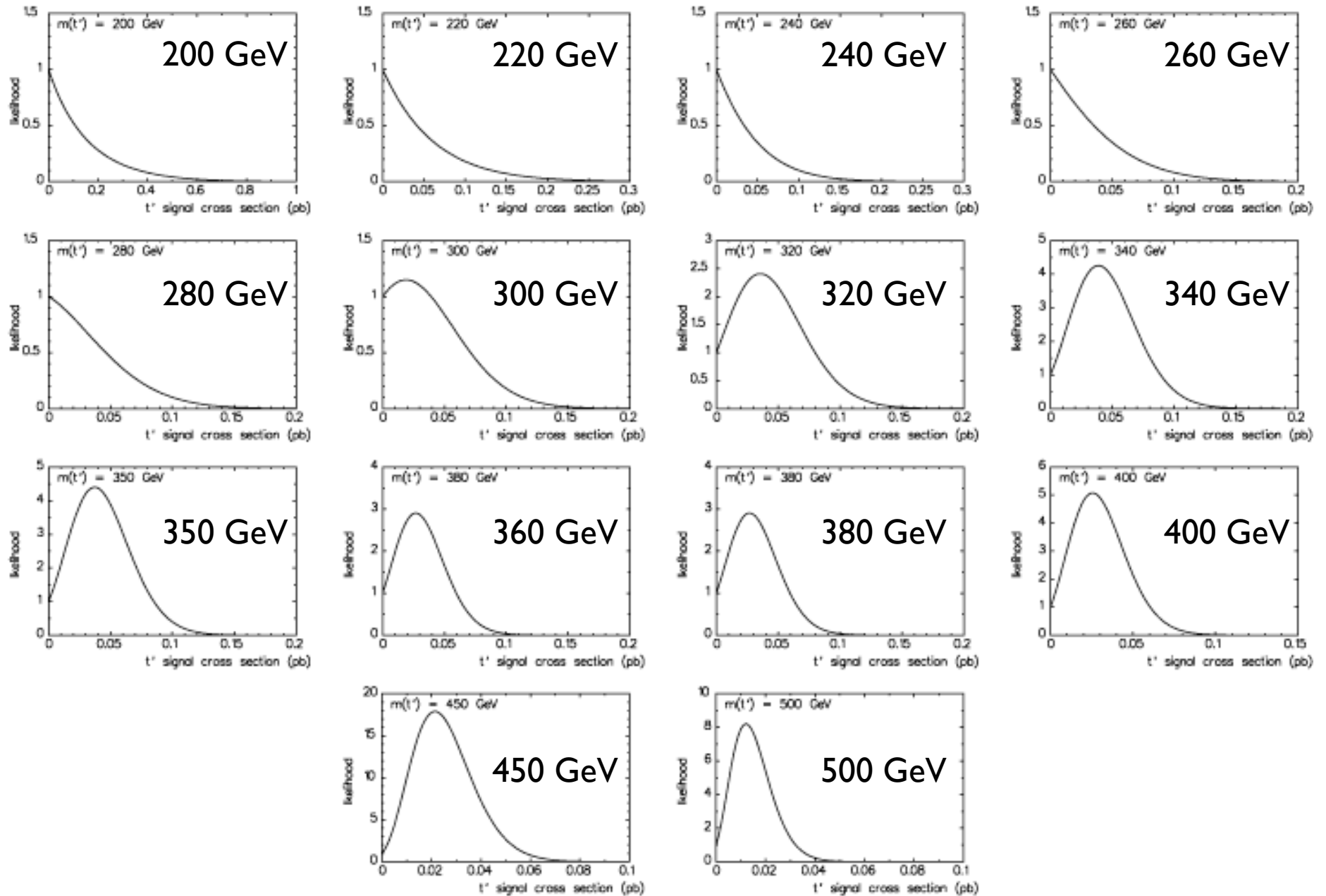   integrated luminosity, ID scale factors, background cross sections

2. shape(+normalization) uncertainties
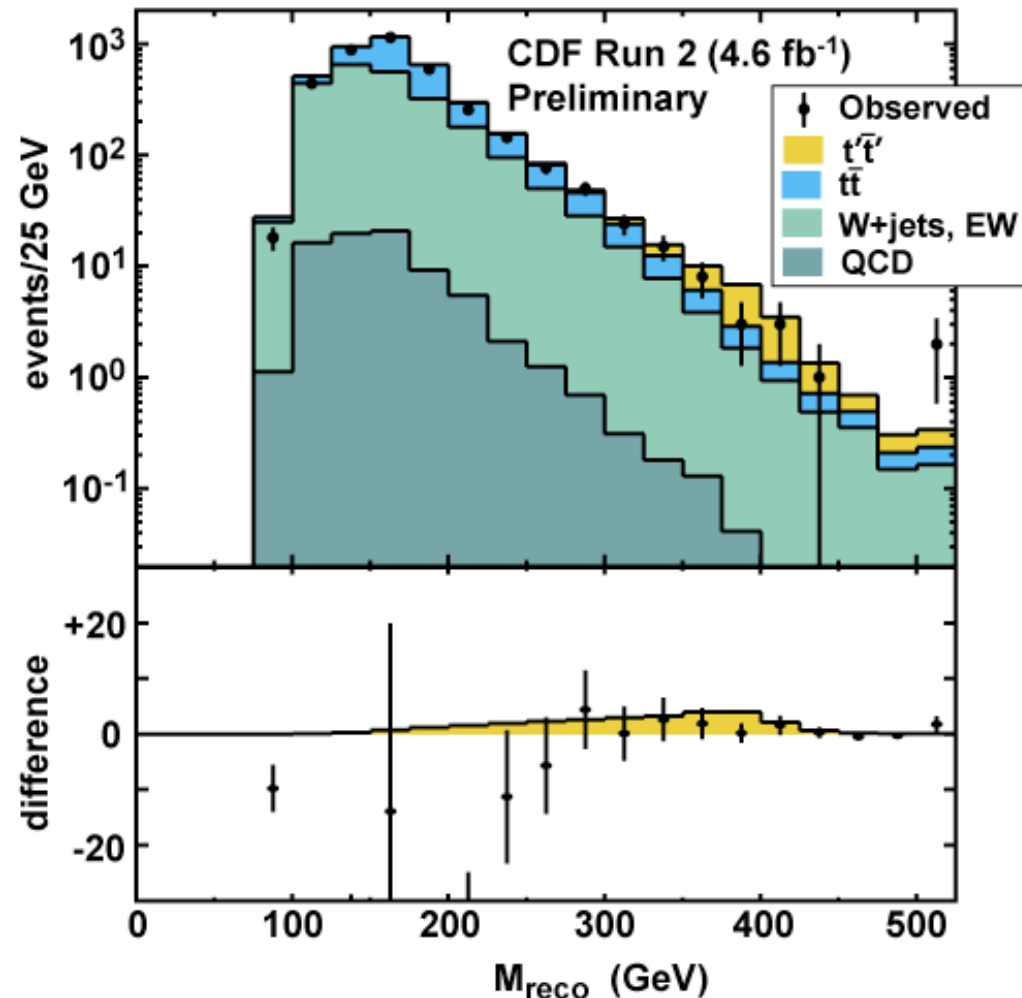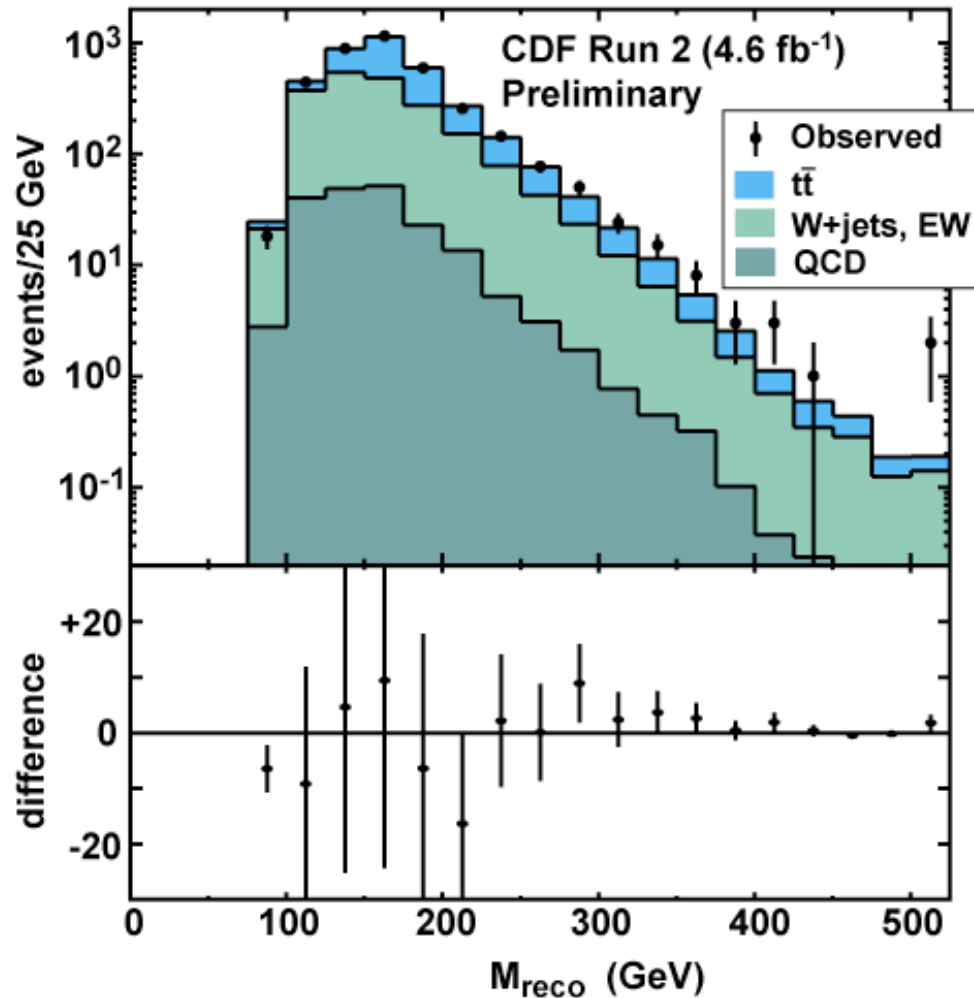   jet energy scale, Q^2 scale, ISR/FSR

3. MC statistics
   handled using "Barlow-Beeston lite" method; bins combined automatically to ensure accuracy
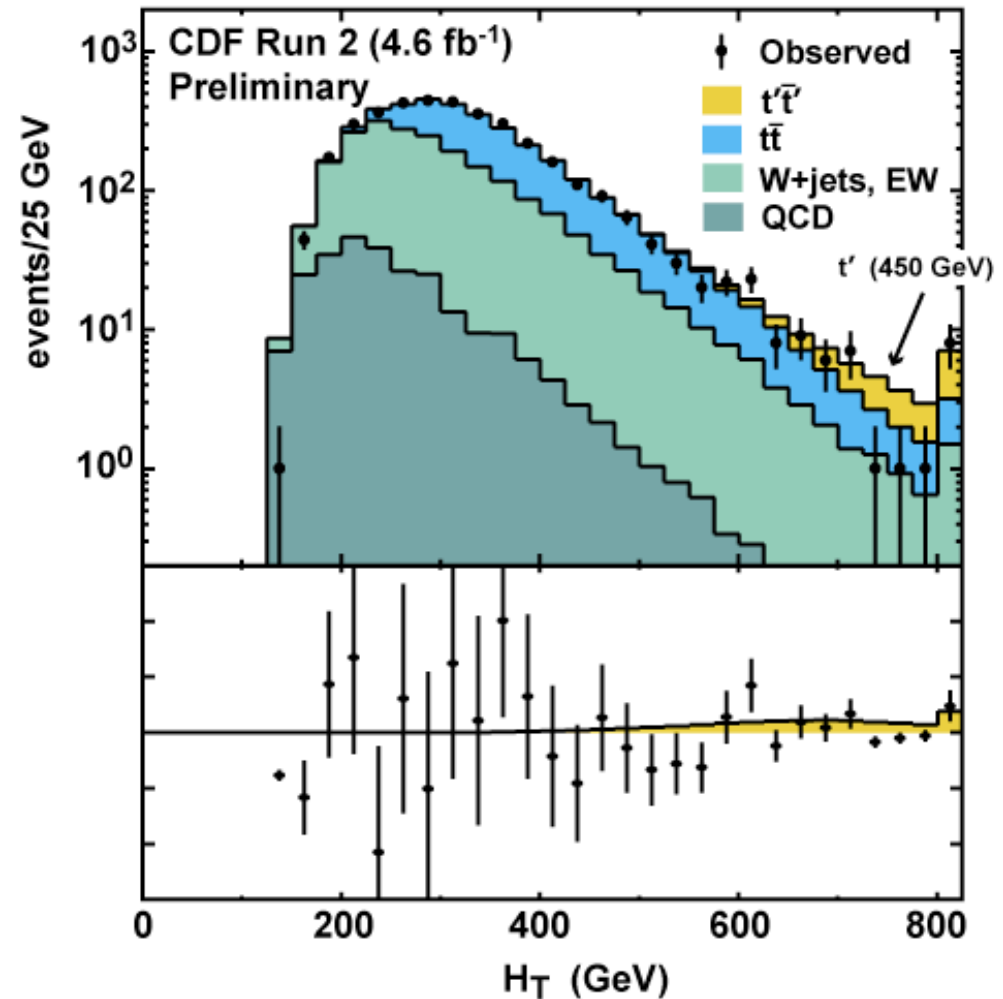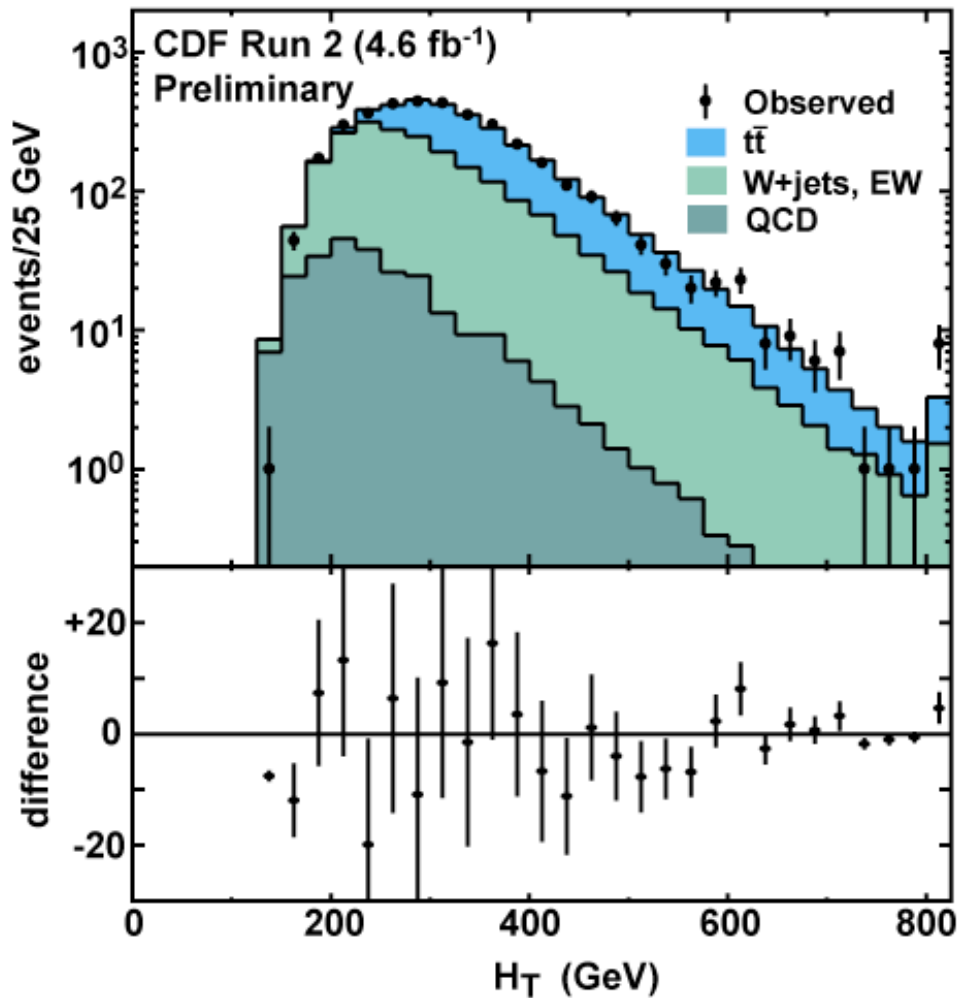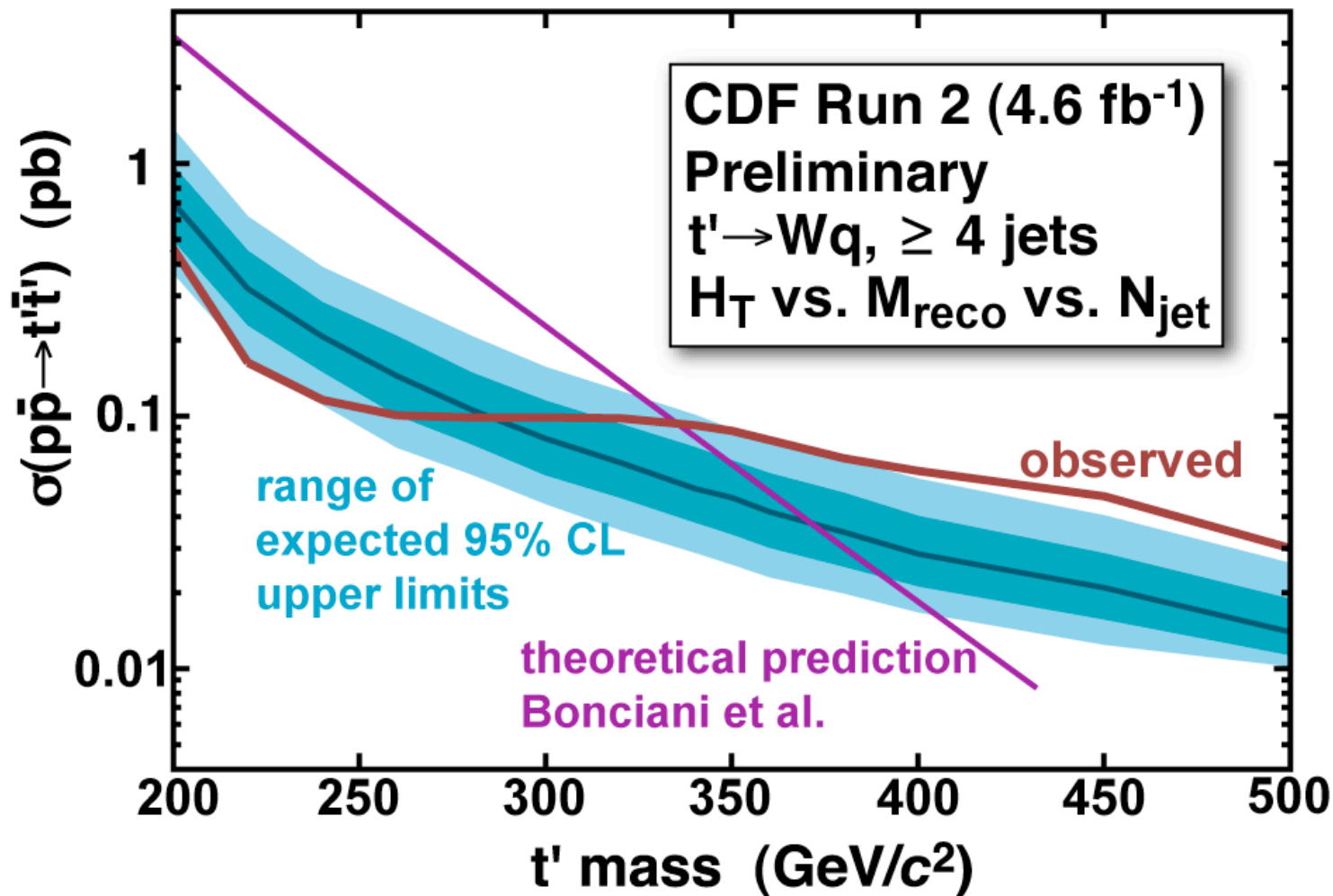
Fit results for t′

Fit results

Peak region fits much better with no signal present!

Fit results

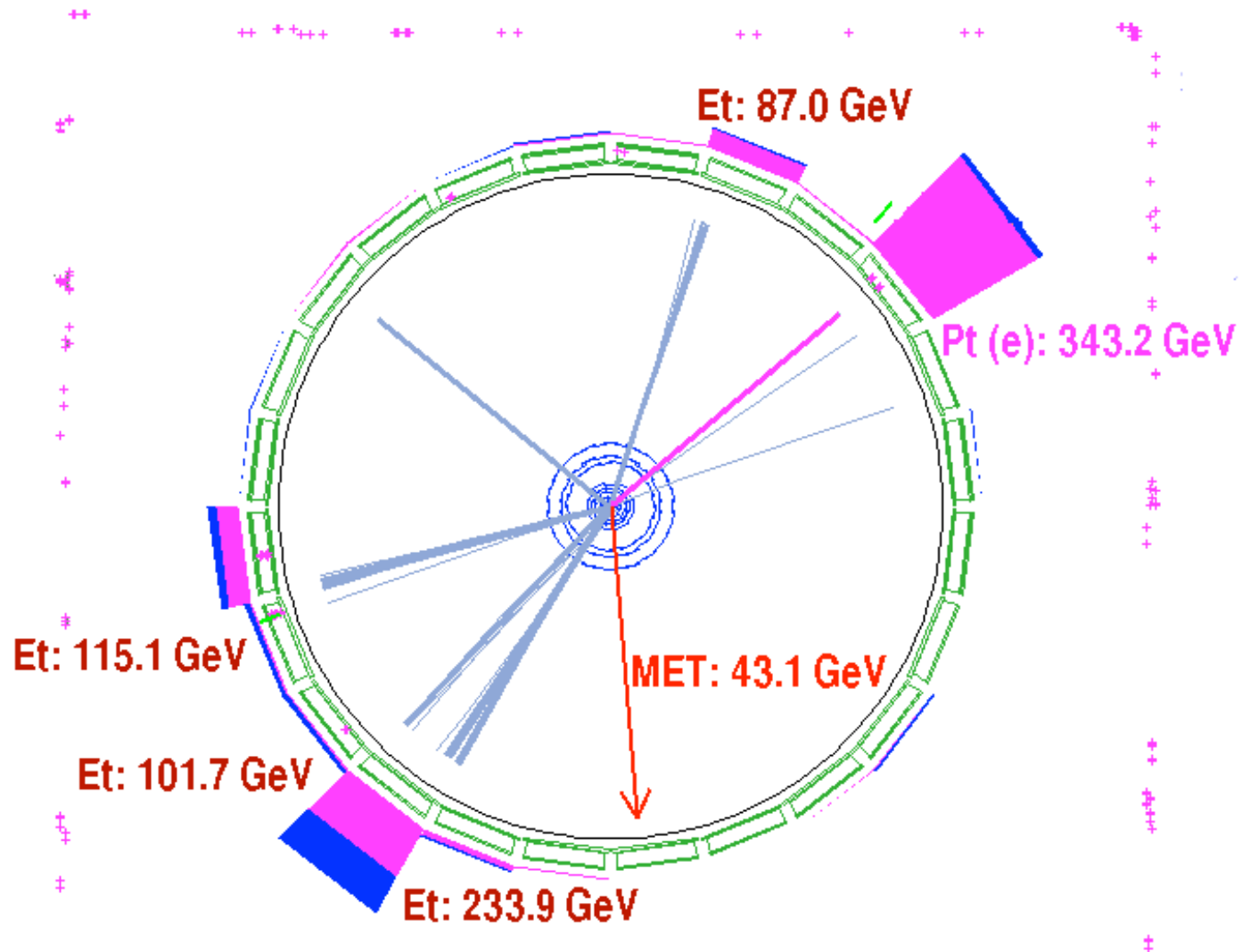H$_T$ fits fits well with or without signal present

t′ limit curve

$m(t′) > 335$ GeV at 95% CL

Significance of t′ excess?

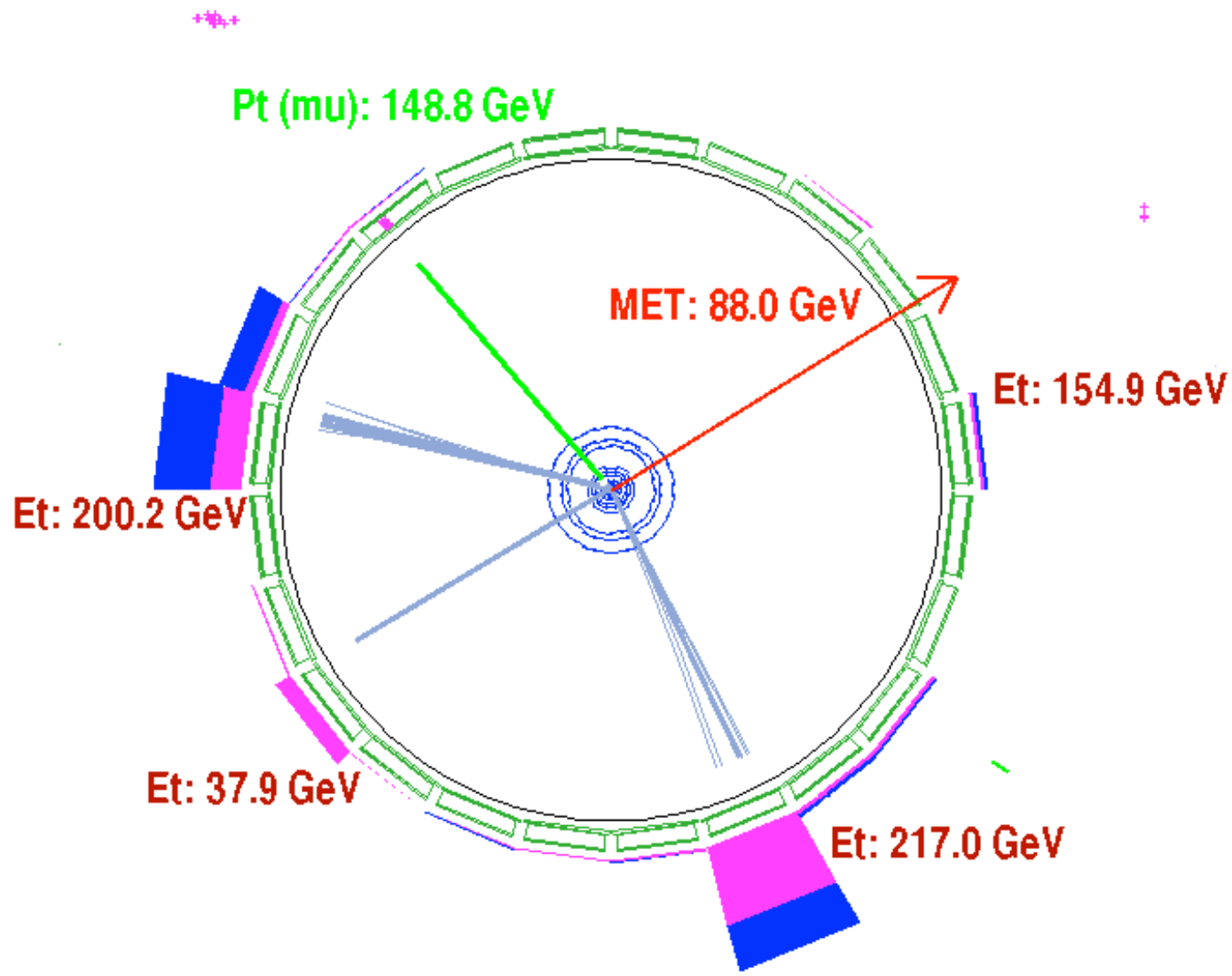- There is no statistically significant excess, it's really less than 2 sigma

- But what <u>are</u> these overflow events?

  - Have continued to increase with more data: now see 10, expect ~4-5

  - Look like ordinary top lepton+jets but with huge H_T or M_{reco}

High-H$_T$ events in t' search

Et: 87.0 GeV

Pt (e): 343.2 GeV

Et: 115.1 GeV

Et: 101.7 GeV

MET: 43.1 GeV

Et: 233.9 GeV

High-H$_T$ events in t' search

Pt (mu): 148.8 GeV

MET: 88.0 GeV

Et: 154.9 GeV

Et: 200.2 GeV

Et: 37.9 GeV

Et: 217.0 GeV

High-H$_T$ events in t' search

Et: 32.2 GeV

Et: 343.3 GeV

Pt (mu): 55.0 GeV

Et: 76.8 GeV

Et: 196.3 GeV   MET: 93.3 GeV
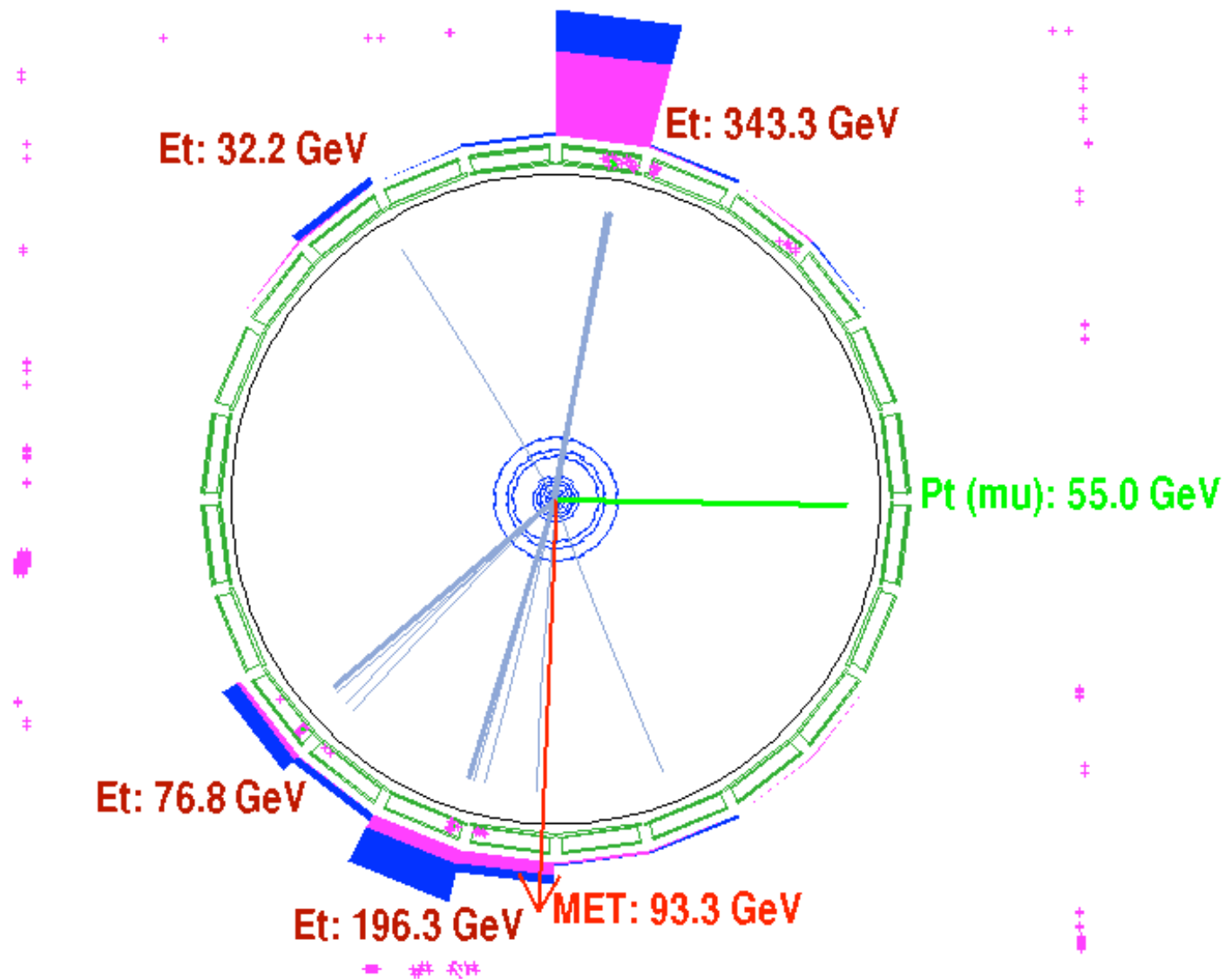
High-H$_T$ events in t' search
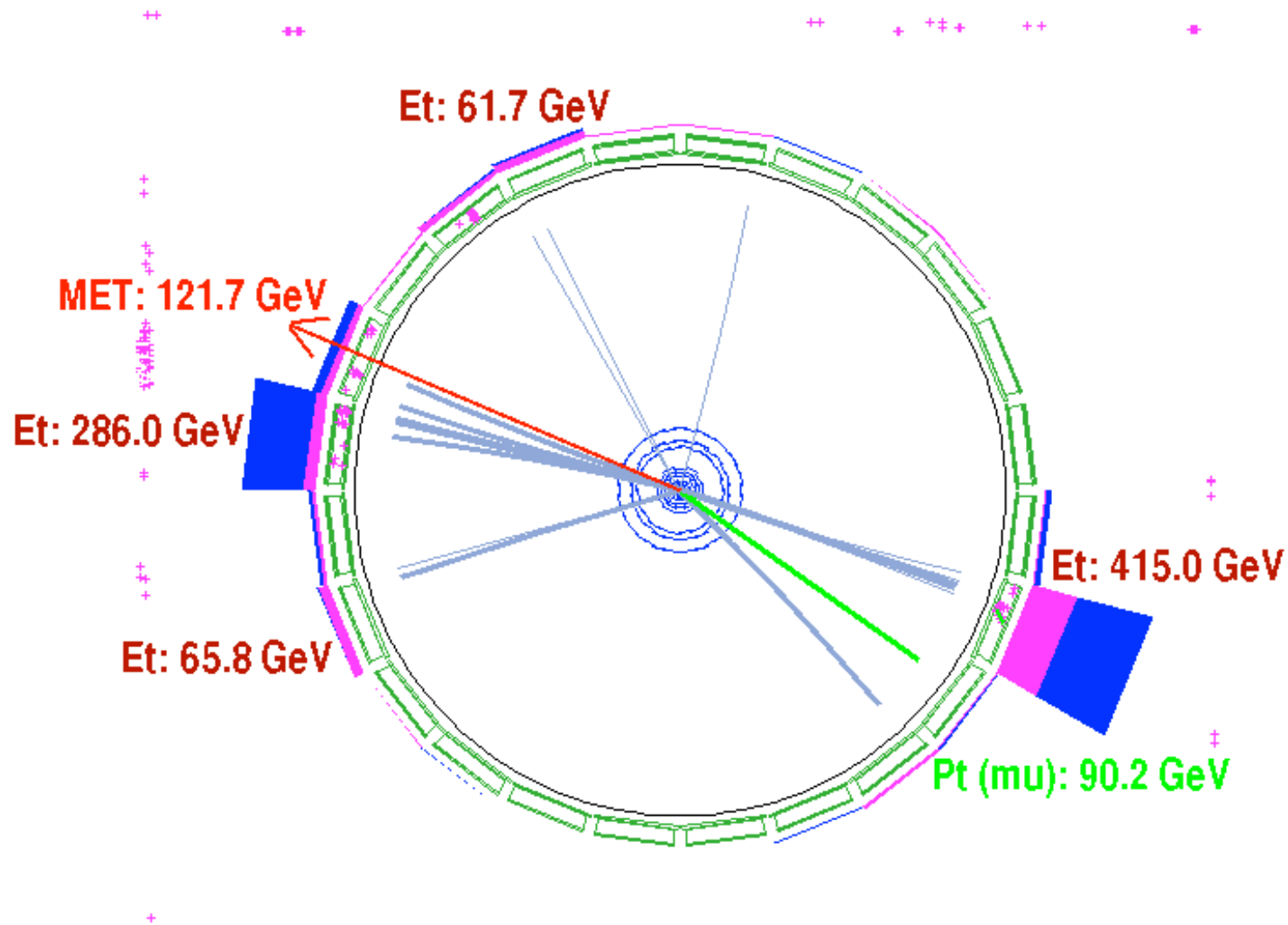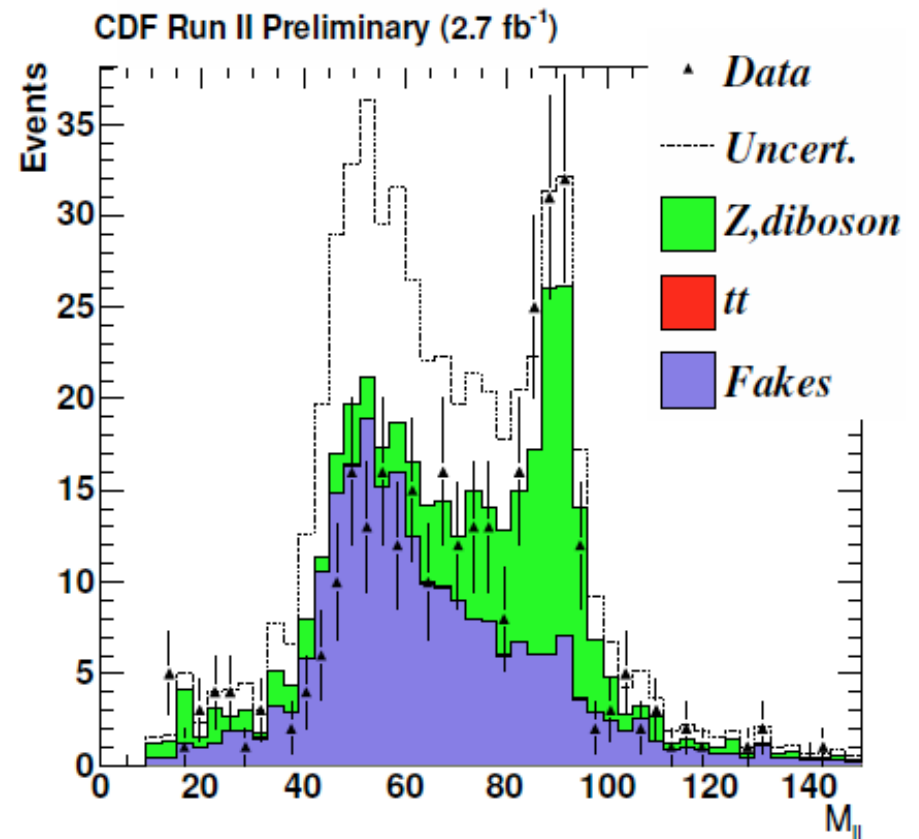
b′ search using LS dileptons

- 4W, 2b final state

  - 2 same-sign e/mu with p$_T$ > 20 GeV

  - at least two jets; at least one b tagged

  - at least 20 GeV missing E$_T$

- low background in SM: fakes, conversions, Z/diboson

CDF Run II Preliminary (2.7 fb⁻¹)

Source	ee	mm	em	ll
$Z, diboson$	0.03 ± 0.015	0.02 ± 0.01	0.04 ± 0.02	0.1 ± 0.05
tt	0.17 ± 0.017	0.06 ± 0.006	0.22 ± 0.022	0.5 ± 0.05
$W + jets$	0.56 ± 0.56	0.34 ± 0.34	0.47 ± 0.47	1.4 ± 1.4
Total	0.8 ± 0.56	0.4 ± 0.34	0.7 ± 0.47	1.9 ± 1.4
Data	0	1	1	2

b′ search using LS dileptons
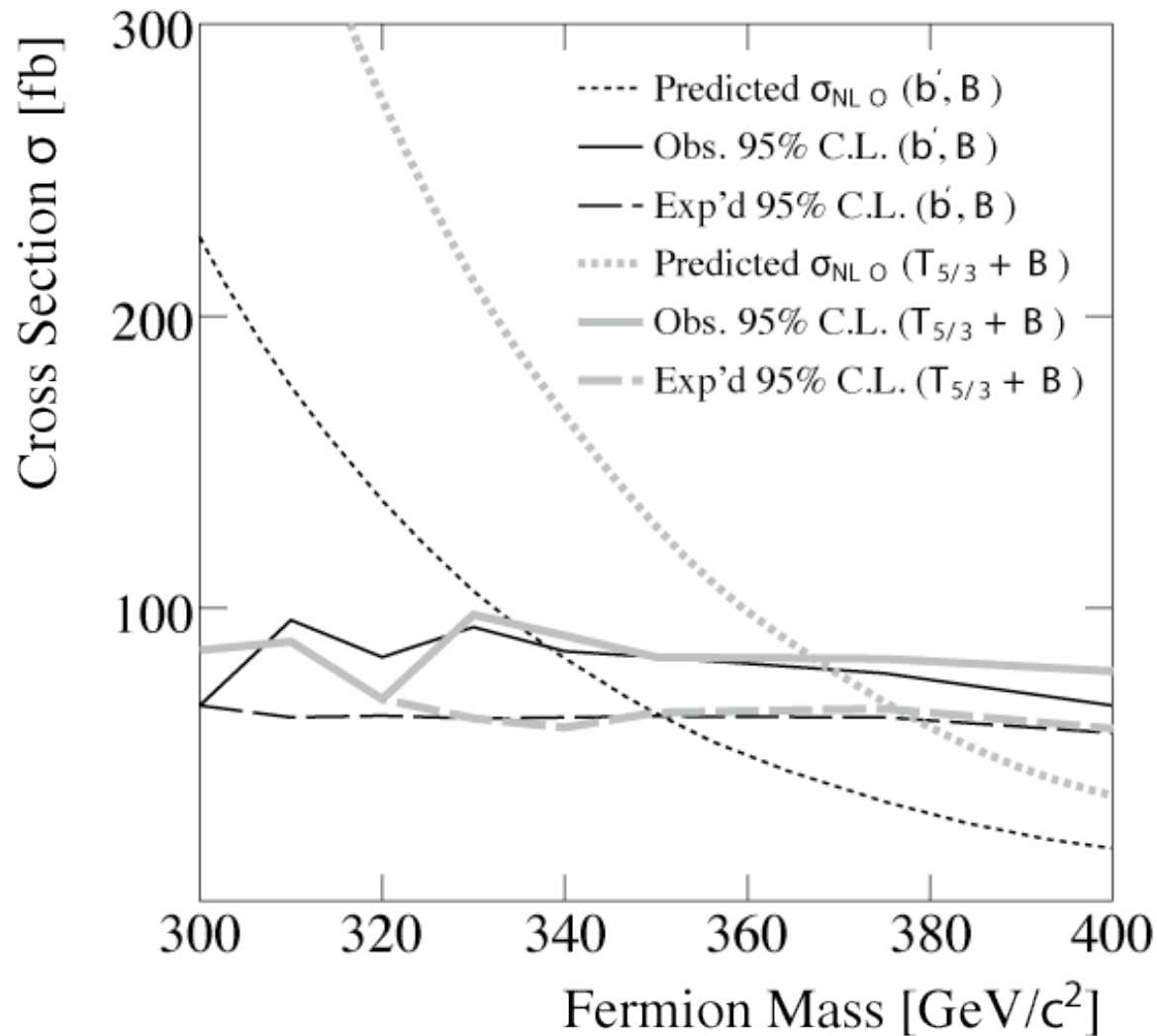
m(b′) > 338 GeV
at 95% CL

The big picture

t' searches
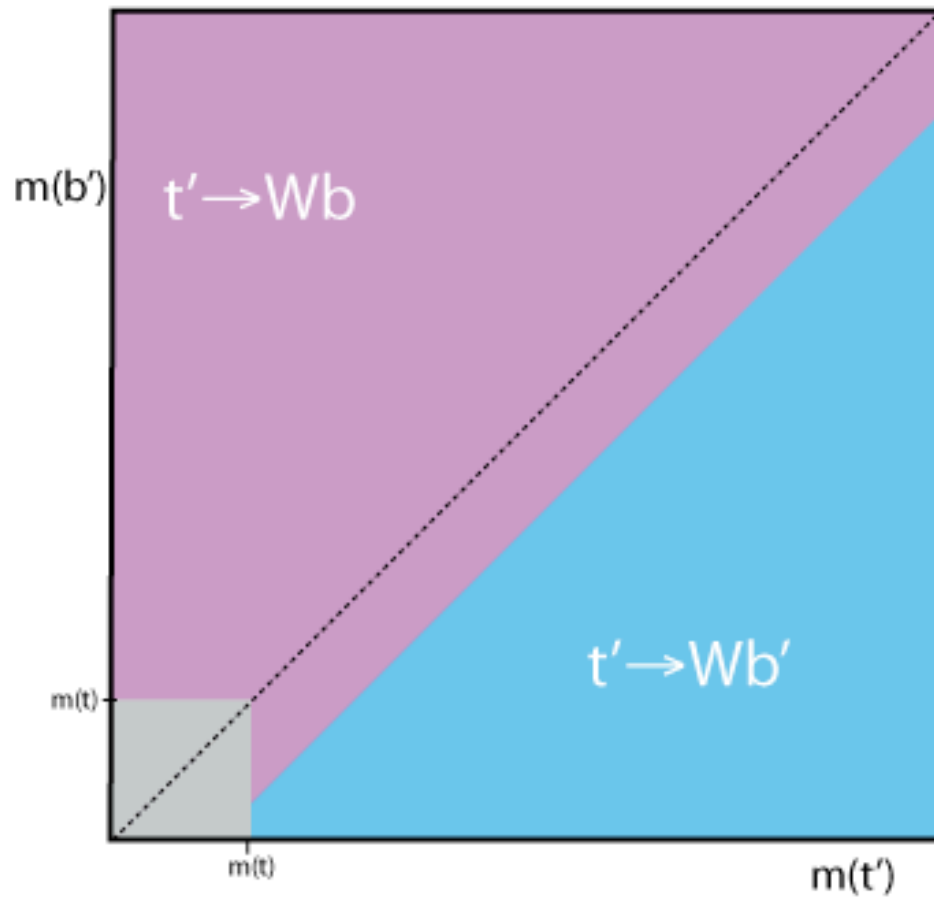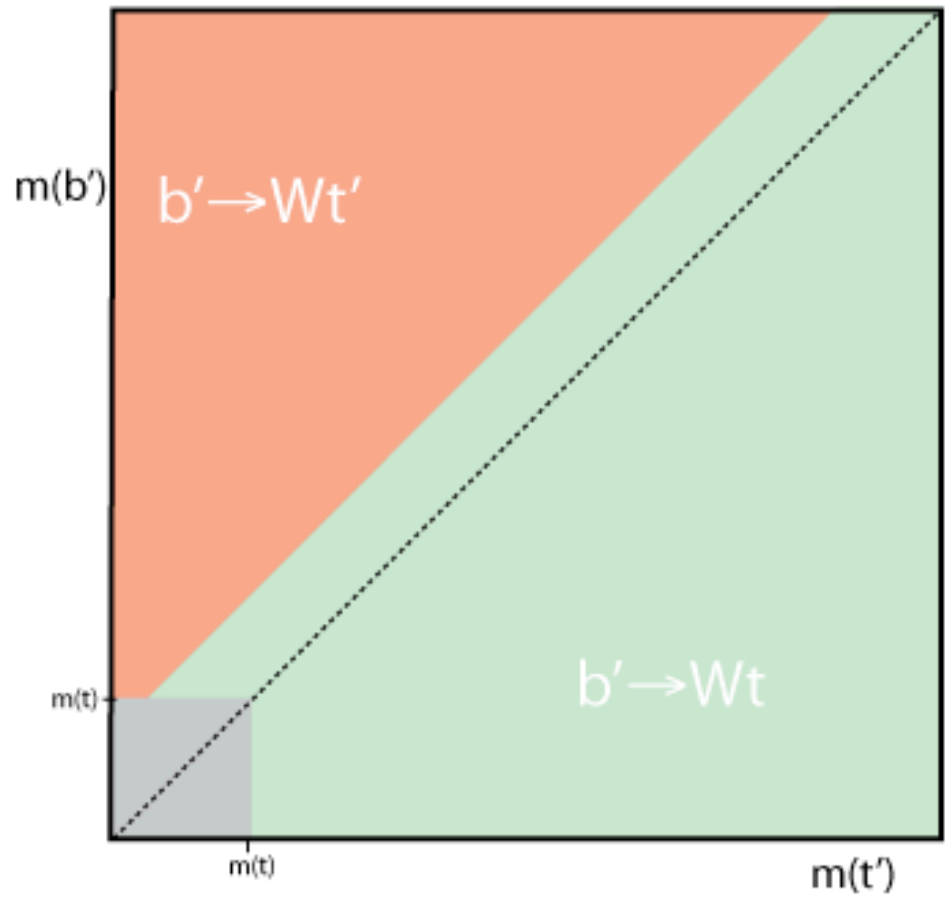
$m(b')$ $t' \rightarrow Wb$ $t' \rightarrow Wb'$ $m(t)$ $m(t)$ $m(t')$
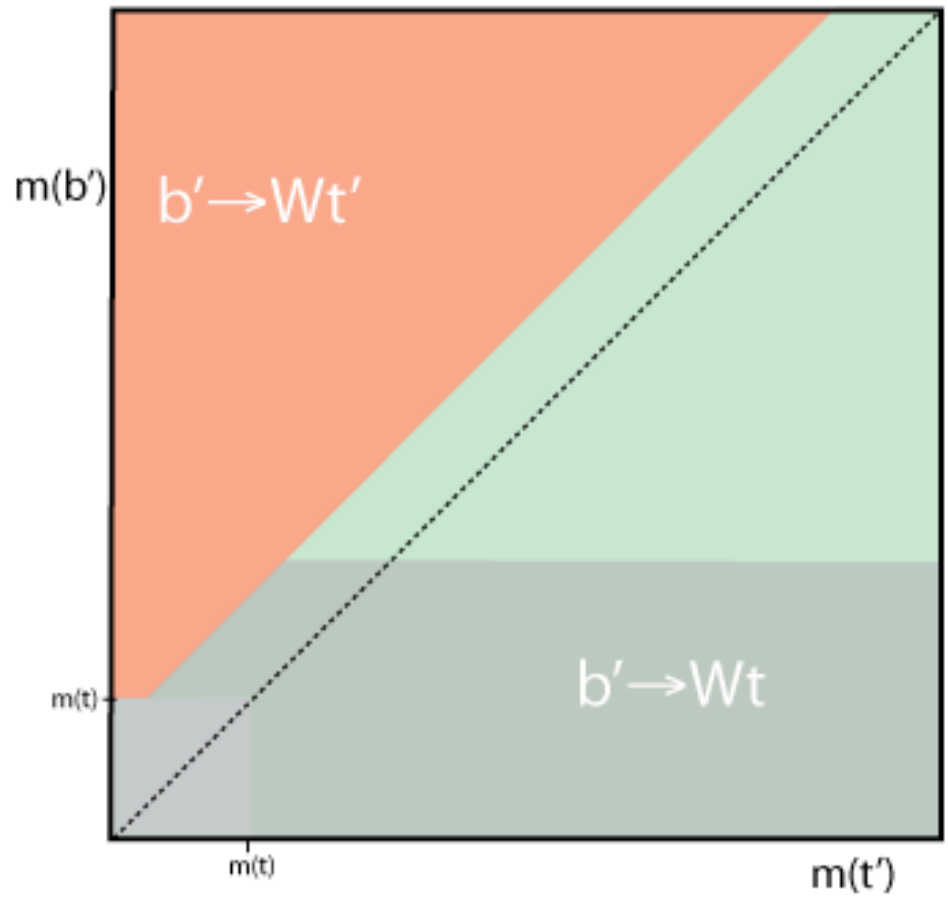
b' searches

$m(b')$ $b' \rightarrow Wt'$ $b' \rightarrow Wt$ $m(t)$ $m(t)$ $m(t')$

The big picture

t' searches

$m(b')$ $t' \to Wb$

$t' \to Wb'$

$m(t)$

$m(t)$ $m(t')$

b' searches

$m(b')$ $b' \to Wt'$

$b' \to Wt$

$m(t)$

$m(t)$ $m(t')$

The big picture

t' searches

$m(b')$

$t' \rightarrow Wb$

$t' \rightarrow Wb'$

$m(t)$

$m(t)$

$m(t')$

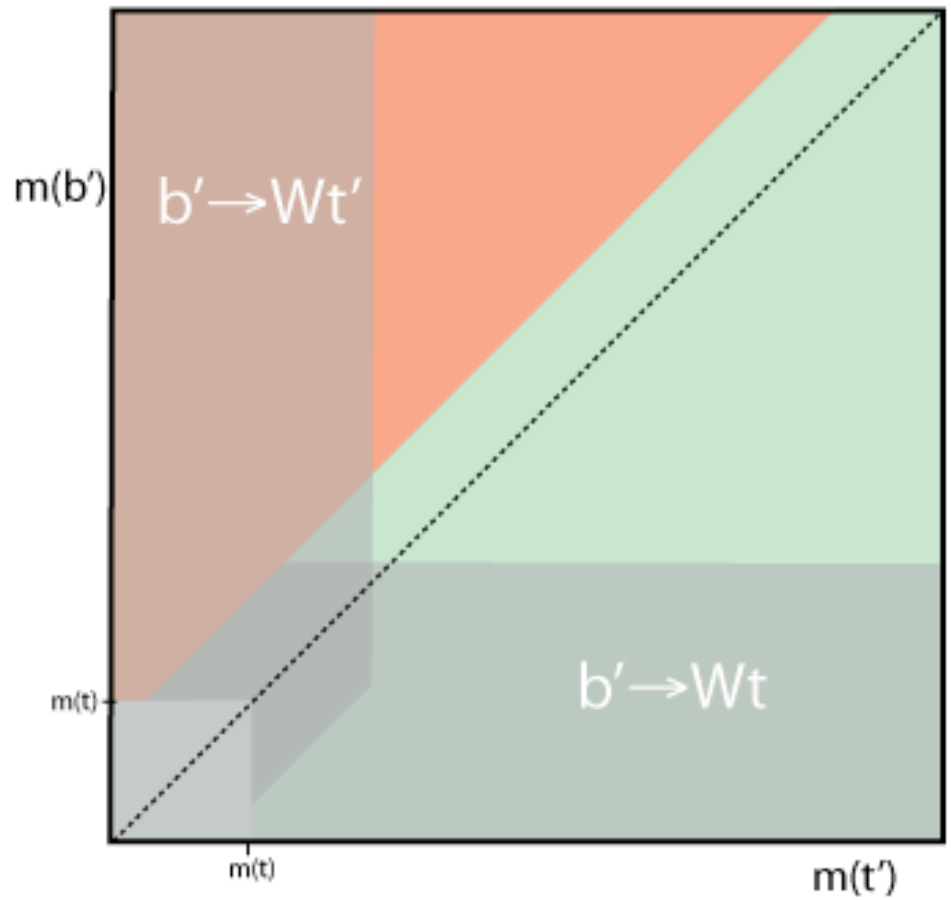b' searches

$m(b')$

$b' \rightarrow Wt'$

$b' \rightarrow Wt$

$m(t)$

$m(t)$

$m(t')$

The big picture

t' searches

$m(b')$ $t'{\rightarrow}Wb$ 2W2b

6W2b

$t'{\rightarrow}Wb'$

$m(t)$ $m(t)$ $m(t')$

b' searches

$m(b')$ $b'{\rightarrow}Wt'$ 4W2b

4W2b

$b'{\rightarrow}Wt$

$m(t)$ $m(t)$ $m(t')$

The big picture

t' searches

2W2b

$t' \rightarrow Wb$

6W2b

$t' \rightarrow Wb'$

m(b')

m(t)

m(t)

m(t')

b' searches

4W2b

$b' \rightarrow Wt'$

4W2b

$b' \rightarrow Wt$

m(b')

m(t)

m(t)

m(t')
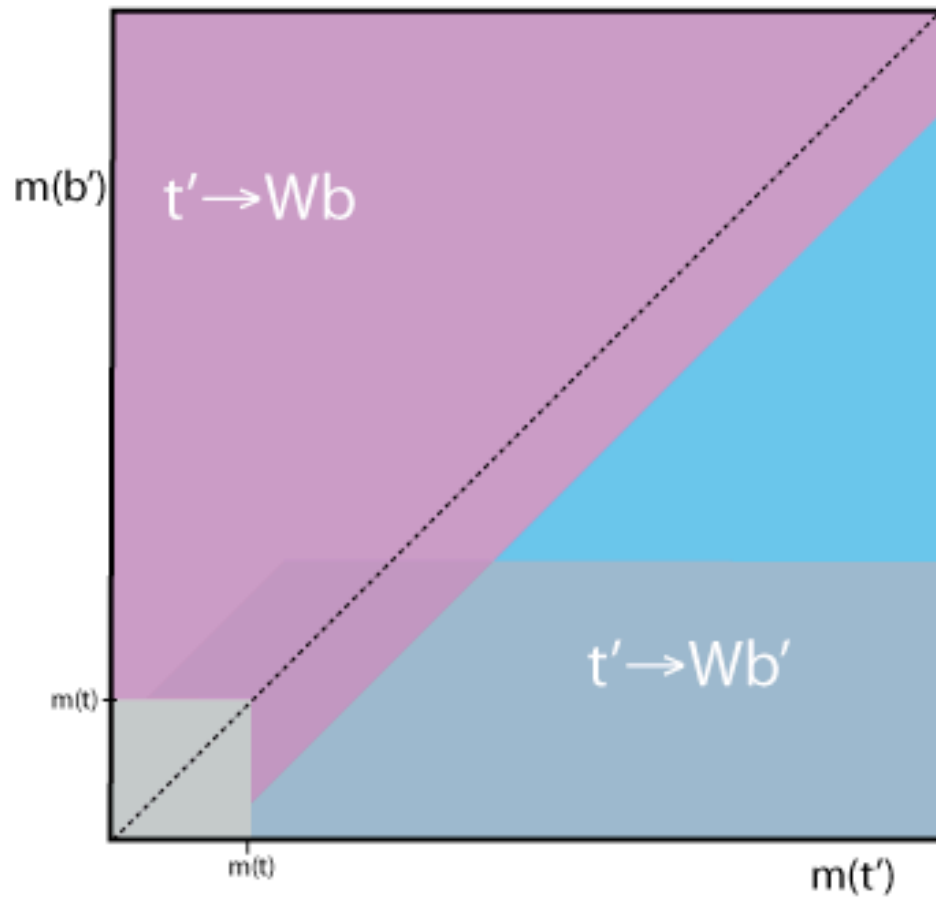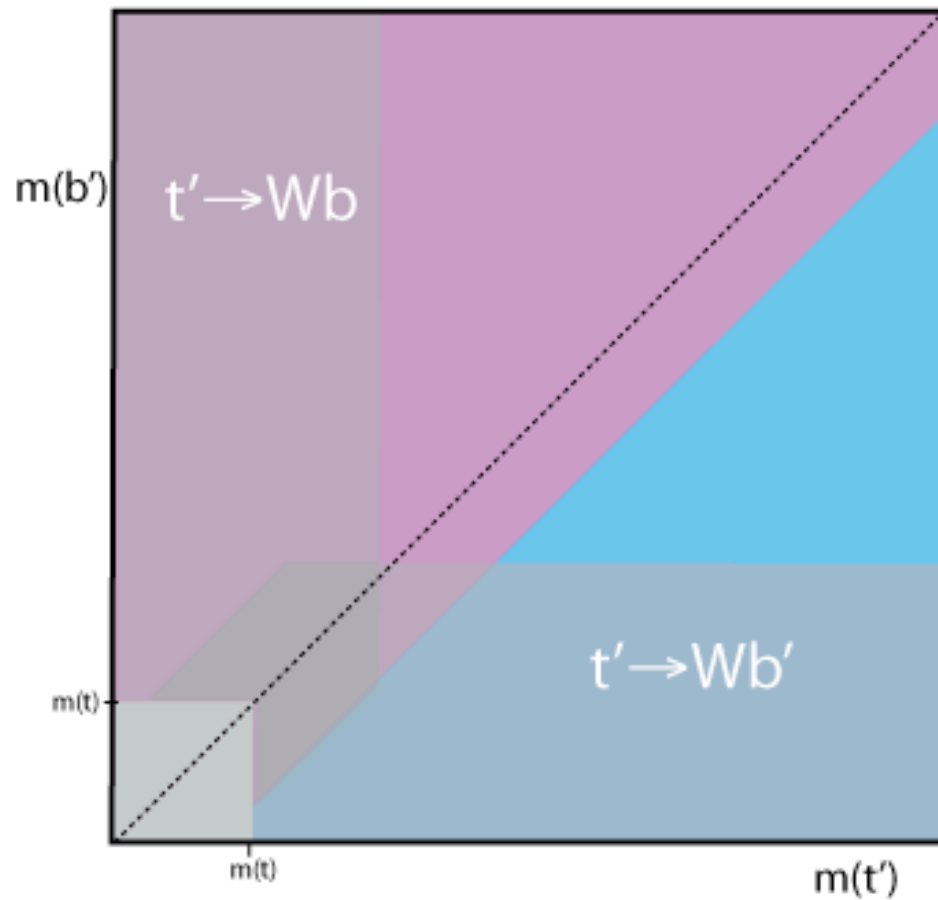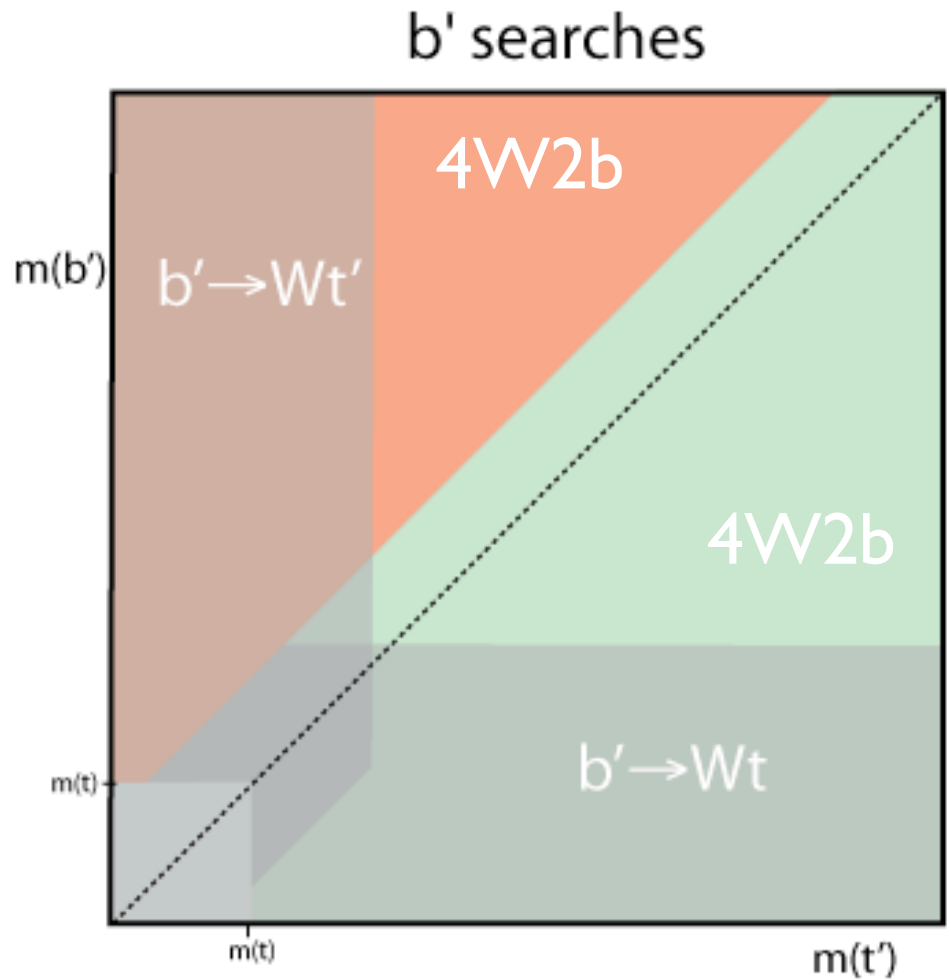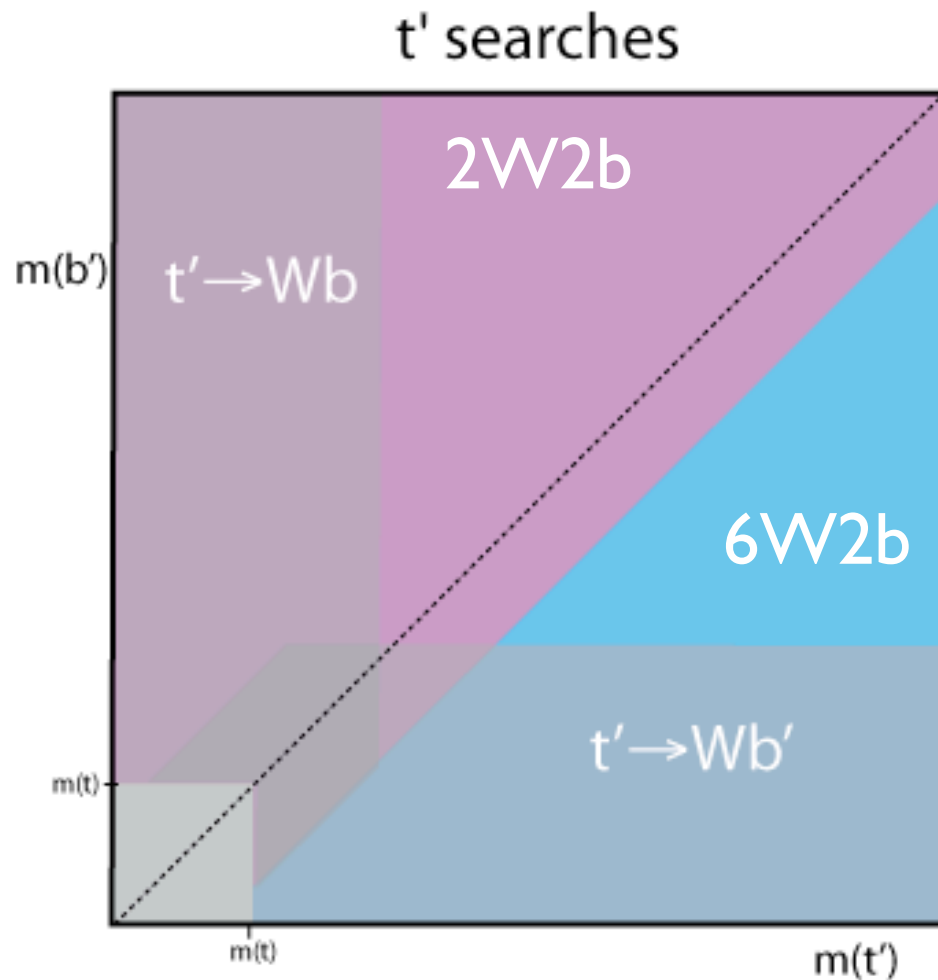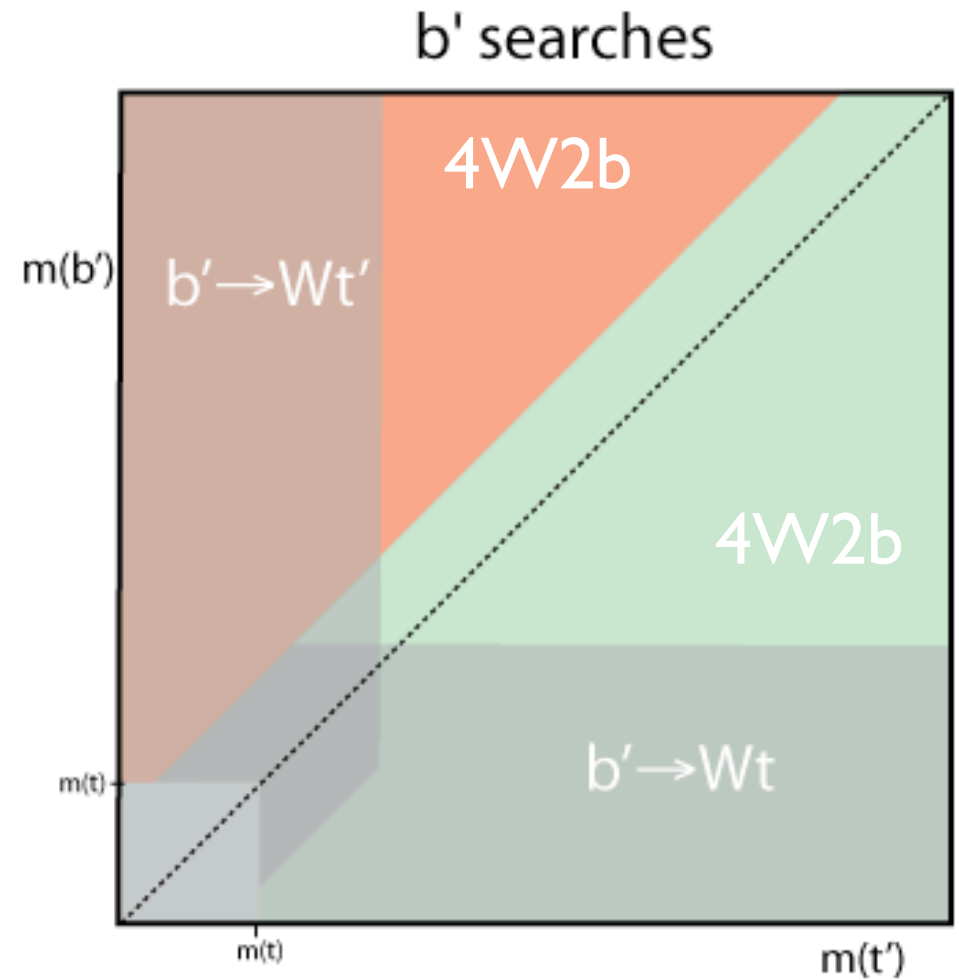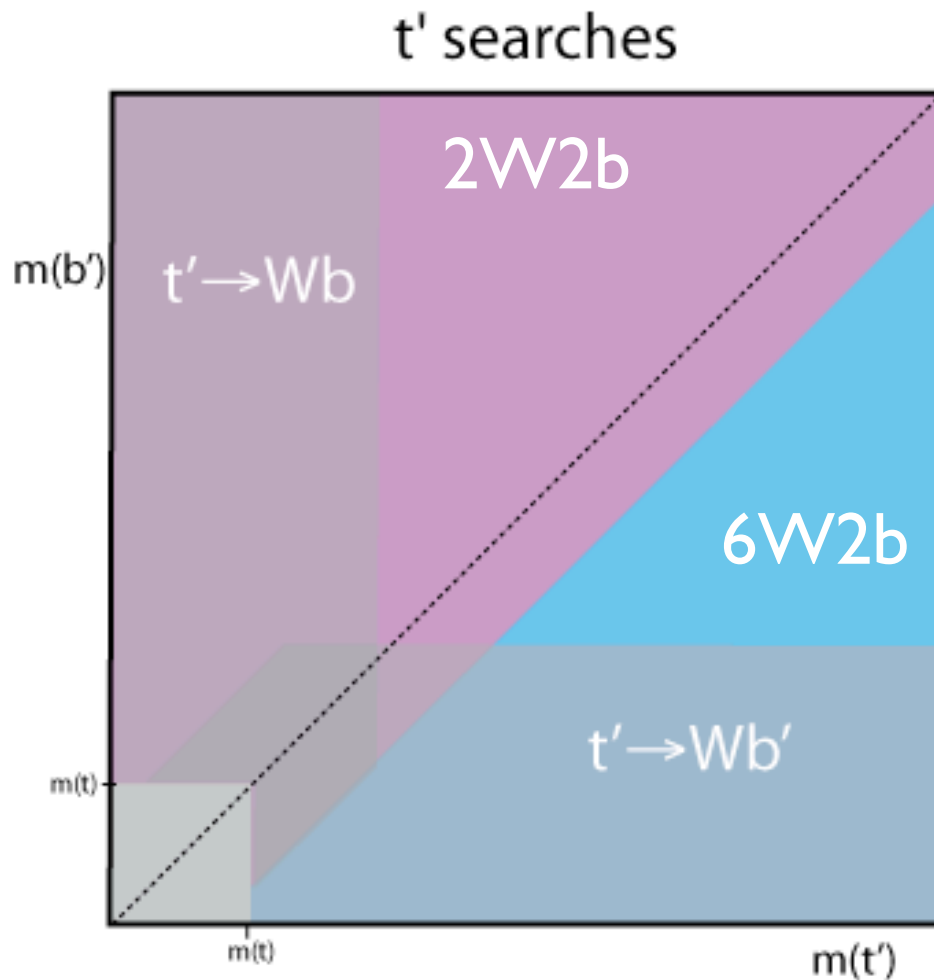
- at least 4 W's, 2b's, no matter what!

The big picture

- at least 4 W's, 2b's, no matter what!

- energy of LHC will win quickly...

A variant?

- It could be that $t' \to tZ$, $b' \to bZ$ play a strong role (S. Martin, arXiv:0910.2732)

t' searches

2Z2W2b

$t' \to Zt$

2Z2W2b

$t' \to Wb'$

m(b')

m(t)

m(t)

m(t')

b' searches

2Z4W2b

$b' \to Wt'$

2Z2b

$b' \to Zb$

m(b')

m(t)

m(t)

m(t')